

Claims

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1. A method of operating a camless internal combustion engine, comprising:

(A) operating said engine using a normally liquid or gaseous fuel composition; and

(B) lubricating said engine using a low-phosphorus or phosphorus-free lubricating oil composition, said low-phosphorus or phosphorus-free lubricating oil composition optionally containing an extreme-pressure additive comprised of metal and phosphorus, provided the amount of phosphorus contributed to said low-phosphorus or phosphorus-free lubricating oil composition by said extreme-pressure additive does not exceed about 0.08% by weight based on the weight of said low-phosphorus or phosphorus-free lubricating oil composition.

2. The method of claim 1 wherein said method further comprises the following additional steps:

(C) removing part of said low-phosphorus or phosphorus-free lubricating oil composition from said engine, said removed part of said low-phosphorus or phosphorus-free lubricating oil composition (i) being combined with said fuel composition and consumed with said fuel composition as said engine is operated or (ii) being combined with the exhaust gas from said engine and removed from said engine with said exhaust gas; and

(D) adding an additional amount of said low-phosphorus or phosphorus-free lubricating oil composition to said engine to replace said removed part of said low-phosphorus or phosphorus-free lubricating oil composition.

3. The method of claim 1 wherein said engine is comprised of a camless valve train.

3 4. The method of claim 1 wherein the intake and exhaust valves employed with said engine are electrically actuated, hydraulically actuated, or electrohydraulically actuated.

5 5. The method of claim 1 wherein each intake and exhaust valve employed with said engine can vary its lift schedule for various engine operating conditions.

10 6. The method of claim 1 wherein said engine comprises from 1 to about 12 cylinders.

15 7. The method of claim 1 wherein said engine comprises about 4 to about 8 cylinders.

8 8. The method of claim 1 wherein said engine has 2 to about 6 valves per cylinder.

20 9. The method of claim 1 wherein said engine has one or two intake valves and one or two exhaust valves per cylinder.

25 10. The method of claim 2 wherein the combination of said fuel composition and said low-phosphorus or phosphorus-free lubricating oil composition formed in step (C) is comprised of about 0.01% to about 5% by weight of said low-phosphorus or phosphorus-free lubricating oil composition.

11. The method of claim 2 wherein during step (C) said removed part of said low-phosphorus or phosphorus-free lubricating oil composition is introduced into said fuel composition in the fuel tank, fuel return line, fuel injectors, intake

E1) manifold, positive crankcase ventilation system, exhaust gas recirculation system, or air intake system of the engine.

5 12. The method of claim 2 wherein the engine is equipped with an exhaust gas aftertreatment device and said removed part of said low-phosphorus or phosphorus-free lubricating oil composition is combined with said exhaust gas upstream of said exhaust gas aftertreatment device.

10 13. The method of claim 1 wherein said engine is a compression-ignition engine.

14. The method of claim 1 wherein said fuel composition is a diesel fuel composition.

15 15. The method of claim 1 wherein said fuel composition is a low sulfur diesel fuel composition.

20 16. The method of claim 1 wherein said engine is a spark ignition engine equipped with an exhaust gas aftertreatment device.

17. The method of claim 1 wherein said fuel composition is a gasoline fuel composition.

25 18. The method of claim 1 wherein said fuel composition is an unleaded gasoline fuel composition.

19. The method of claim 1 wherein said fuel composition is a gasoline fuel composition having a sulfur content of up to about 300 ppm.

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20. The method of claim 1 wherein said fuel composition is a gasoline fuel composition having a chlorine content of no more than about 10 ppm.

21. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is comprised of components that add only C, H, O or N, and optionally Si to said composition.

22. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition has a viscosity of up to about 16.3 cSt at 100°C.

23. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition has an SAE Viscosity Grade of 0W, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W-50, 5W-60, 10W, 10W-20, 10W-30, 10W-40 or 10W-50.

24. The composition of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition has a high-temperature/high-shear viscosity at 150°C of up to about 4 centipoise.

25. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is comprised of a mineral base oil.

26. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is comprised of a poly-alpha-olefin base oil.

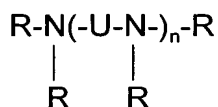
27. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is comprised of an acylated nitrogen-containing compound having a substituent of at least about 10 aliphatic carbon atoms.

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28. The method of claim 27 wherein said acylated nitrogen-containing compound is derived from a carboxylic acylating agent and at least one amino compound containing at least one -NH- group, said acylating agent being linked to said amino compound through an imido, amido, amidine or salt linkage.

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29. The method of claim 28 wherein said amino compound is an alkylenepolyamine represented by the formula:



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wherein U is an alkylene group of from about 2 to about 10 carbon atoms; each R is independently a hydrogen atom, a hydrocarbyl group, a hydroxy-substituted hydrocarbyl group, or an amine-substituted hydrocarbyl group containing up to about 30 carbon atoms, with the proviso that at least one R is a hydrogen atom; and n is 1 to about 10.

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30. The method of claim 28 wherein said amino compound is an alkylenepolyamine of 2 to about 8 amino groups.

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31. The method of claim 28 wherein said carboxylic acylating agent is a mono- or polycarboxylic acid or anhydride containing an aliphatic hydrocarbyl substituent of at least about 30 carbon atoms.

32. The method of claim 27 wherein said acylated nitrogen-containing compound is a polyisobutene substituted succinimide containing at least about 50 aliphatic carbon atoms in the polyisobutene group.

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33. The method of claim 27 wherein said acylated nitrogen-containing compound has a chlorine content of no more than about 50 ppm.

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34. The method of claim 1 wherein said extreme-pressure additive is a compound represented by the formula



wherein in Formula (A),  $\text{X}^1$ ,  $\text{X}^2$  and  $\text{X}^3$  and  $\text{X}^4$  are independently O or S, a and b are independently zero or 1, and  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^3$  are independently hydrocarbyl groups and  $\text{R}^3$  can be hydrogen, provided the amount of phosphorus contributed to said first lubricating oil composition by said salt does not exceed about 0.04% by weight based on the weight of said first lubricating oil composition.

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35. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is characterized by the absence of an extreme-pressure additive comprised of metal and phosphorus.

36. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is a low-ash lubricating oil composition which further comprises an ash-producing detergent or dispersant.

37. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is characterized by the absence of an ash-producing detergent or dispersant.

38. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition is comprised of at least one ashless detergent or dispersant, corrosion-inhibiting agent, antioxidant, viscosity modifier, pour point depressant, friction modifier, fluidity modifier, or anti-foam agent.

39. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition has a sulfur content of no more than about 250 ppm.

40. The method of claim 1 wherein said low-phosphorus or phosphorus-free lubricating oil composition has a chlorine content of no more than about 10 ppm.

41. A method of operating a camless internal combustion engine, comprising:

(A) operating said engine using a normally liquid hydrocarbon fuel composition; and

(B) lubricating said engine using a low-phosphorus or phosphorus-free lubricating oil composition, said low-phosphorus or phosphorus-free lubricating oil composition comprising an acylated nitrogen-containing compound having a substituent of at least about 10 aliphatic carbon atoms; said low-phosphorus or phosphorus-free lubricating oil composition optionally containing an extreme-pressure additive comprised of metal and phosphorus, provided the amount of phosphorus contributed to said low-phosphorus or phosphorus-free lubricating oil composition by said extreme-pressure additive does not exceed about 0.08% by weight based on the weight of said low-phosphorus or phosphorus-free lubricating oil composition.

42. A method of operating a camless internal combustion engine, comprising:

(A) operating said engine using a normally liquid hydrocarbon fuel composition;

(B) lubricating said engine using a low-phosphorus or phosphorus-free lubricating oil composition, said low-phosphorus or phosphorus-free lubricating oil composition comprising an acylated nitrogen-containing compound having a substituent of at least about 10 aliphatic carbon atoms; said low-phosphorus or phosphorus-free lubricating oil composition being characterized by the absence of extreme-pressure additives comprised of metal and phosphorus;

(C) removing part of said low-phosphorus or phosphorus-free lubricating oil composition from said engine, said removed part of said low-phosphorus or phosphorus-free lubricating oil composition (i) being combined with said fuel composition and consumed with said fuel composition as said engine is operated or (ii) being combined with the exhaust gas from said engine and removed from said engine with said exhaust gas; and

(D) adding an additional amount of said low-phosphorus or phosphorus-free lubricating oil composition to said engine to replace said removed part of said low-phosphorus or phosphorus-free lubricating oil composition.

43. A method of operating a camless spark ignition internal combustion engine equipped with an exhaust gas aftertreatment device, said method comprising:

(A) operating said engine using a gasoline fuel composition;

(B) lubricating said engine using a low-phosphorus or phosphorus-free lubricating oil composition, said low-phosphorus or phosphorus-free lubricating oil composition being characterized by the absence of extreme-pressure additives comprised of metal and phosphorus;



5 (C) removing part of said low-phosphorus or phosphorus-free lubricating oil composition from said engine, said removed part of said low-phosphorus or phosphorus-free lubricating oil composition (i) being combined with said fuel composition and consumed with said fuel composition as said engine is operated or (ii) being combined with the exhaust gas from said engine upstream of said exhaust gas aftertreatment device and removed from said engine with said exhaust gas; and

10 (D) adding an additional amount of said low-phosphorus or phosphorus-free lubricating oil composition to said engine to replace said removed part of said low-phosphorus or phosphorus-free lubricating oil composition.

44. A method of operating a camless compression ignition internal combustion engine, said method comprising:

15 (A) operating said engine using a diesel fuel composition;

(B) lubricating said engine using a low-phosphorus or phosphorus-free lubricating oil composition;

20 (C) removing part of said low-phosphorus or phosphorus-free lubricating oil composition from said engine, said removed part of said low-phosphorus or phosphorus-free lubricating oil composition (i) being combined with said fuel composition and consumed with said fuel composition as said engine is operated or (ii) being combined with the exhaust gas from said engine and removed from said engine with said exhaust gas; and

25 (D) adding an additional amount of said low-phosphorus or phosphorus-free lubricating oil composition to said engine to replace said removed part of said low-phosphorus or phosphorus-free lubricating oil composition.